USE OF VERTICAL LIFT PLANETARY AERIAL VECHICLES FOR THE EXPLORATION OF MARS.

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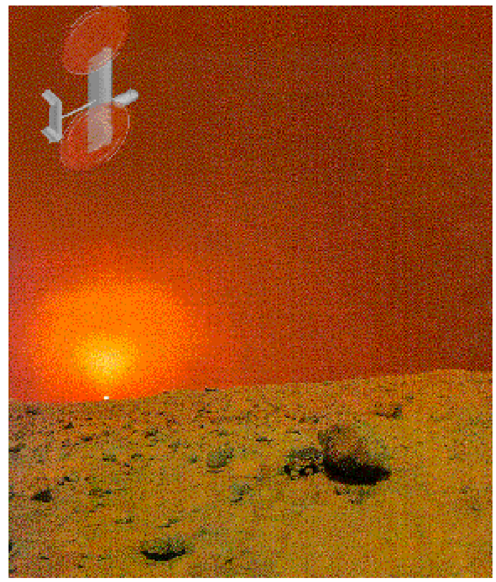
Introduction: Despite the thin, cold, carbon-dioxide-based atmosphere of Mars, recent work at NASA Ames has suggested that vertical lift (based on rotary-wing technology) planetary aerial vehicles could potentially be developed to support Mars exploration missions [1]. The use of robotic vertical lift planetary aerial vehicles (VL PAVs) would greatly augment the science return potential of Mars exploration. Many technical challenges exist in the development of vertical lift vehicles for planetary exploration. It only takes the realization that the world altitude record for a helicopter is less than 40,000 feet (versus flight at the equivalent terrestrial altitude of over 100,000 feet required to match Mars' surface atmospheric density) to appreciate the aeronautical challenges in developing these vehicles. Nonetheless, preliminary work undertaken at NASA Ames and others [2,3] suggest that these vehicles are indeed viable candidates for Mars exploration.

Why vertical lift vehicles for planetary exploration? For the same reason these vehicles are such flexible aerial platforms for terrestrial exploration and transportation: the ability to hover and fly at low-speeds and to take-off and land at unprepared remote sites. Further, autonomous vertical lift planetary aerial vehicles would have the following specific advantages/capabilities for planetary exploration:

- Hover and low-speed flight capability would enable detailed and panoramic survey of remote site(s);
- Vertical lift configurations would enable remote-site sample return to lander platforms, and/or precision placement of scientific probes;
- Soft landing capability for vehicle reuse (i.e. lander refueling and multiple sorties) and remote-site monitoring;
- Hover/soft landing are good fail-safe 'hold' modes for autonomous operation of planetary aerial vehicles;
- Vertical lift planetary aerial vehicles would provide greater range and speed than a rover while performing detailed surveys;
- Vertical lift planetary aerial vehicles would provide greater resolution of surface details, or observation of atmospheric phenomena, than an orbiter;
- Vertical lift vehicles would provide greater access to hazardous terrain than would be provided solely by lander or rover.
- Could act as 'Astronaut Agents' for efficiently and comprehensively conducting scientific exploration.

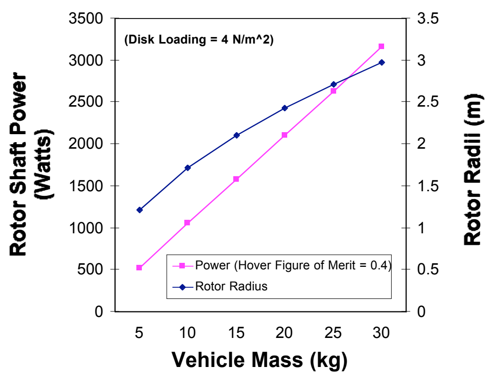


Exploration With a Vertical Lift Component

Opportunities & Challenges:.

Opportunities. Robotic Martian rotorcraft are unique compared to other proposed aerial platforms (aerostats and fixed-wing airplanes) for Mars exploration. The very nature of such a vehicle would be its ability to fly close to and interact with the Martian surface. As was once humorously noted, no one is likely to build runways on Mars. Nonetheless, it is the expectation of the authors that an abbreviated sort of 'evolution of flight' will occur on Mars: balloons will likely be flown first, followed by fixed-wing aircraft, and then rotary-wing/vertical-lift vehicles. These various types of aerial platforms will likely be complementary to each other in their ability to meet unique mission requirements and science objectives. Robotic missions using Martian rotorcraft could include aerial survey work, precision placement of small science probes (or micro-rovers) on the planet's surface, or even support sample return missions by acquiring/retrieving small soil samples from remote sites. Martian rotorcraft could also support the human exploration of Mars. Martian autonomous rotorcraft could act as 'astronaut agents' for the future explorers providing them improved 'mobility' -- and safety.

Technical Challenges. Autonomous vertical lift PAVs will be high-risk and high-payoff development ventures. Though an impressive – and ever-expanding -- amount of data exists for Mars, nonetheless, these data are barely adequate for the purposes of designing and building PAVs. Such vehicles will need to be highly adaptive (from a controls and structures perspective), have conservative performance margins, and will require high degrees of mission/flight autonomy to adequately deal with corresponding levels of uncertainty in the mission and flight environment. Martian autonomous rotorcraft by their nature will have large lifting-surfaces and will be required to have ultra-lightweight construction. This in turn will pose a challenge in making them sufficiently robust to operate in the Martian environment.



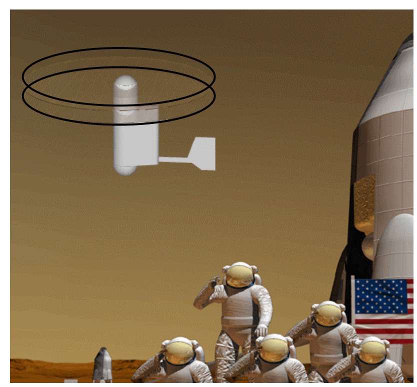
Large, Ultra-lightweight, Fragile…

Early 'Scout' Missions: As noted above, early missions for Martian autonomous rotorcraft will undoubtedly be for aerial survey of the Martian surface. One such aerial scouting mission could focus on mapping a survey area inclusive of the entry error ellipse projected for a follow-up mission.

Two concepts are currently being assessed at NASA Ames for an aerial scout role: an air-deployed autorotating, or partially-powered, 'reelable' rotor design [4,5], and a lander-based, surface-launched, coaxial helicopter design with folding/telescoping rigid blades. Propulsion options include hydrazine 'tip-jets' for the reelable rotor design, and electric motors, or an Akkerman hydrazine reciprocating engine [6], for coaxial helicopter.

Current Status of Work at NASA Ames: Work to date has focussed on conceptual design studies. As a result, reference [1] provided an initial discussion of the technical challenges and opportunities of vertical lift PAVs. In addition to the vehicle studies, a university grant was initiated to develop a conceptual design of a mission/flight control computer architecture for a Martian autonomous rotorcraft. The Year 2000 American Helicopter Society Student Design Competition was initiated focusing on the design topic of a Martian autonomous rotorcraft. Paper design studies from the participating universities have been received and are currently being reviewed by the competition judges. The winning teams of this competition will be announced at the next Annual Forum of the American Helicopter Society.

Ongoing work is focused on the refinement of Ames-generated MARS conceptual designs, as well as initiating development of low-cost proof-of-concept test articles for demonstrating critical MARS technologies – including the development of a hover test stand for testing full-scale rotors at Mars atmospheric densities and a tethered hover flight demonstrator.



Martian Rotorcraft as 'Astronaut Agents'

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